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Hoffmann et al.

[11] **Patent Number: 5,941,214**

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[54] **DEVICE AND METHOD FOR REGULATING THE FUEL PRESSURE IN A HIGH-PRESSURE ACCUMULATOR**

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Related U.S. Application Data

[63] Continuation of application No. PCT/DE97/00902, May 2, 1997.

[51] **Int. Cl.**[6] **F02M 37/04**

[52] **U.S. Cl.** **123/456**; 123/447

[58] **Field of Search** 123/447, 446, 123/456, 497, 514

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Primary Examiner—Carl S. Miller

Attorney, Agent, or Firm—Herbert L. Lerner; Laurence A. Greenberg

[57] **ABSTRACT**

A device and a method are provided for regulating the fuel pressure in a high-pressure accumulator. A volumetric flow regulation and a pressure regulation combine the advantages of regulation of volumetric flow and regulation of pressure with one another and thus achieve increased dynamics and higher efficiency.

10 Claims, 2 Drawing Sheets

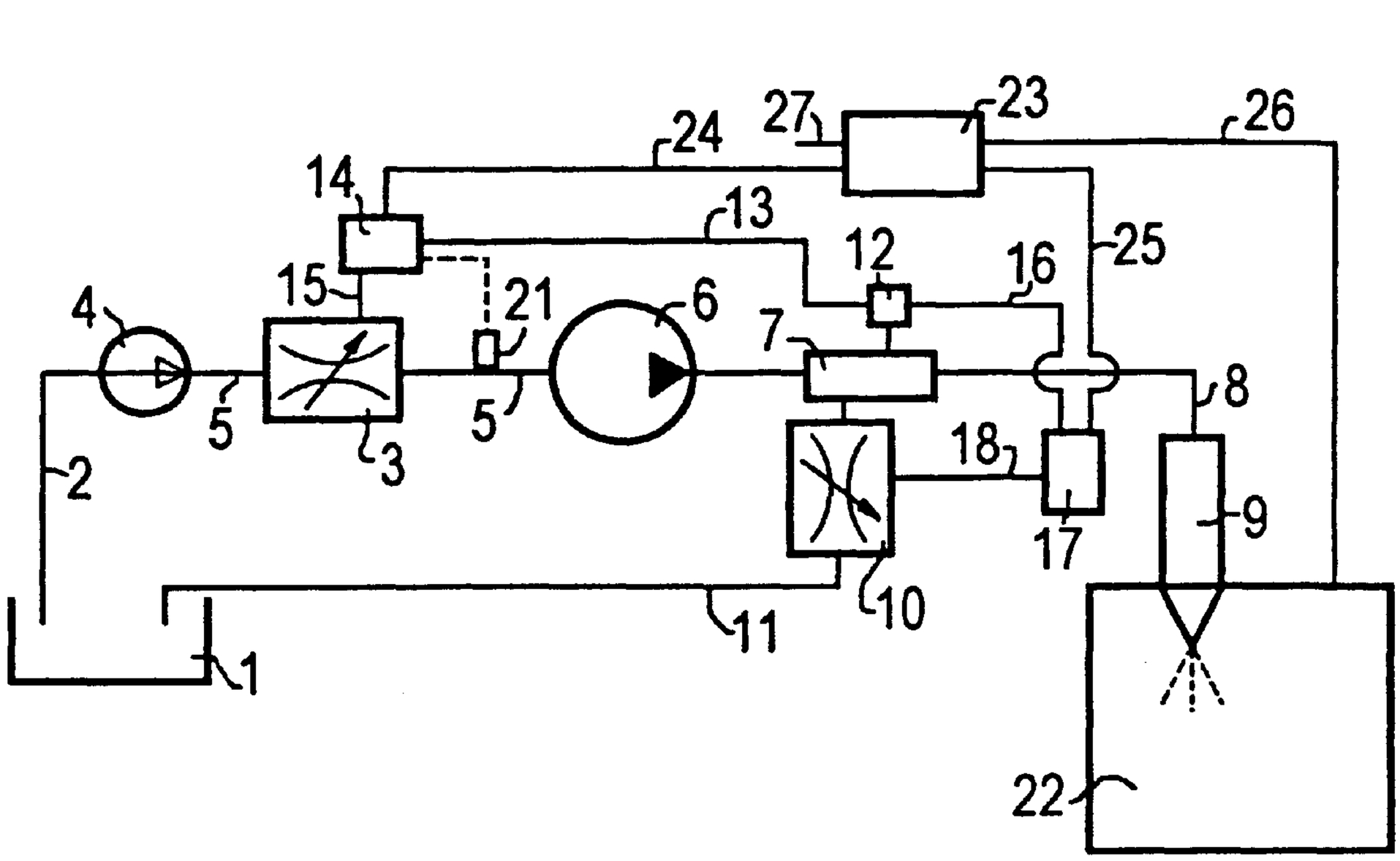

FIG 1

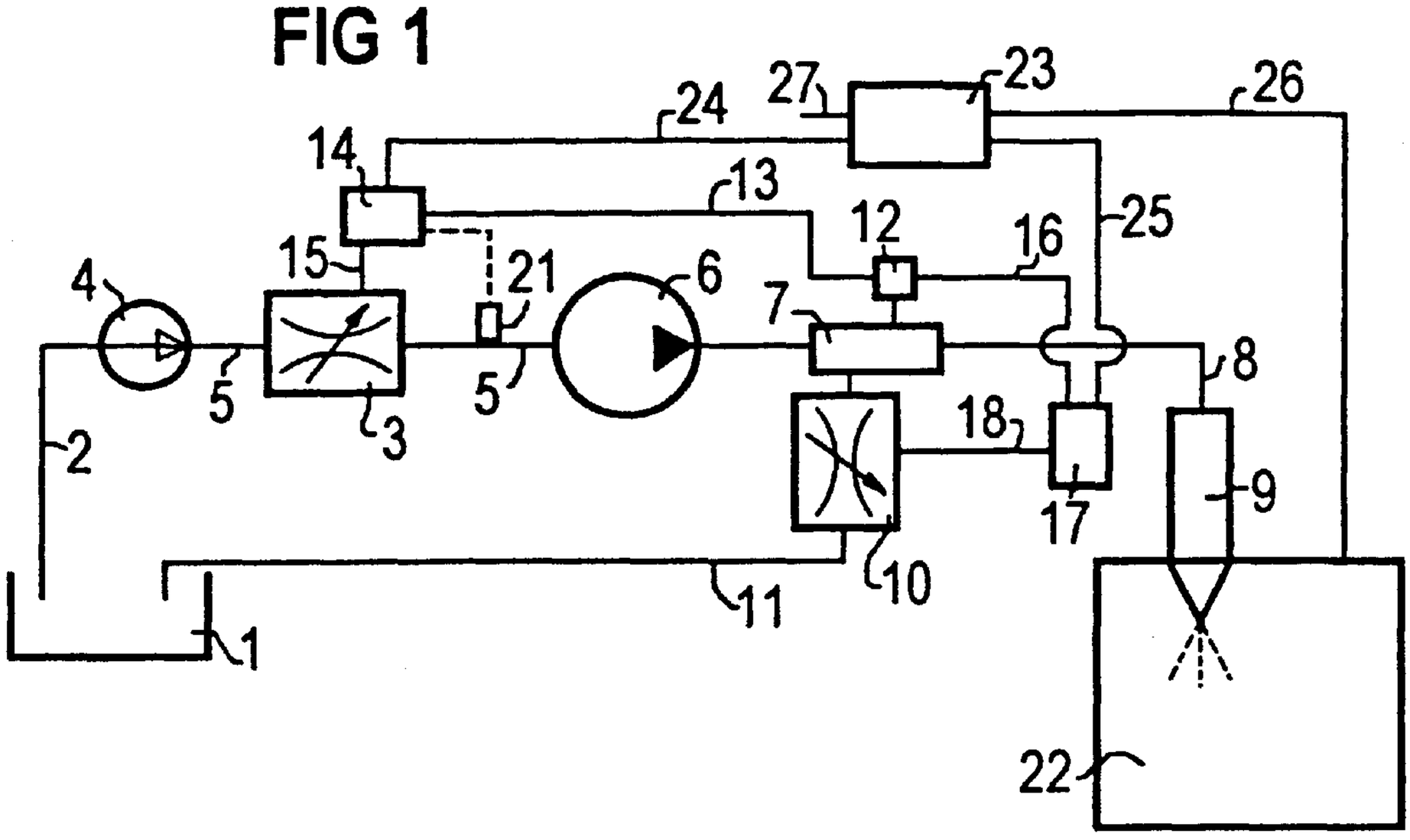
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FIG 2

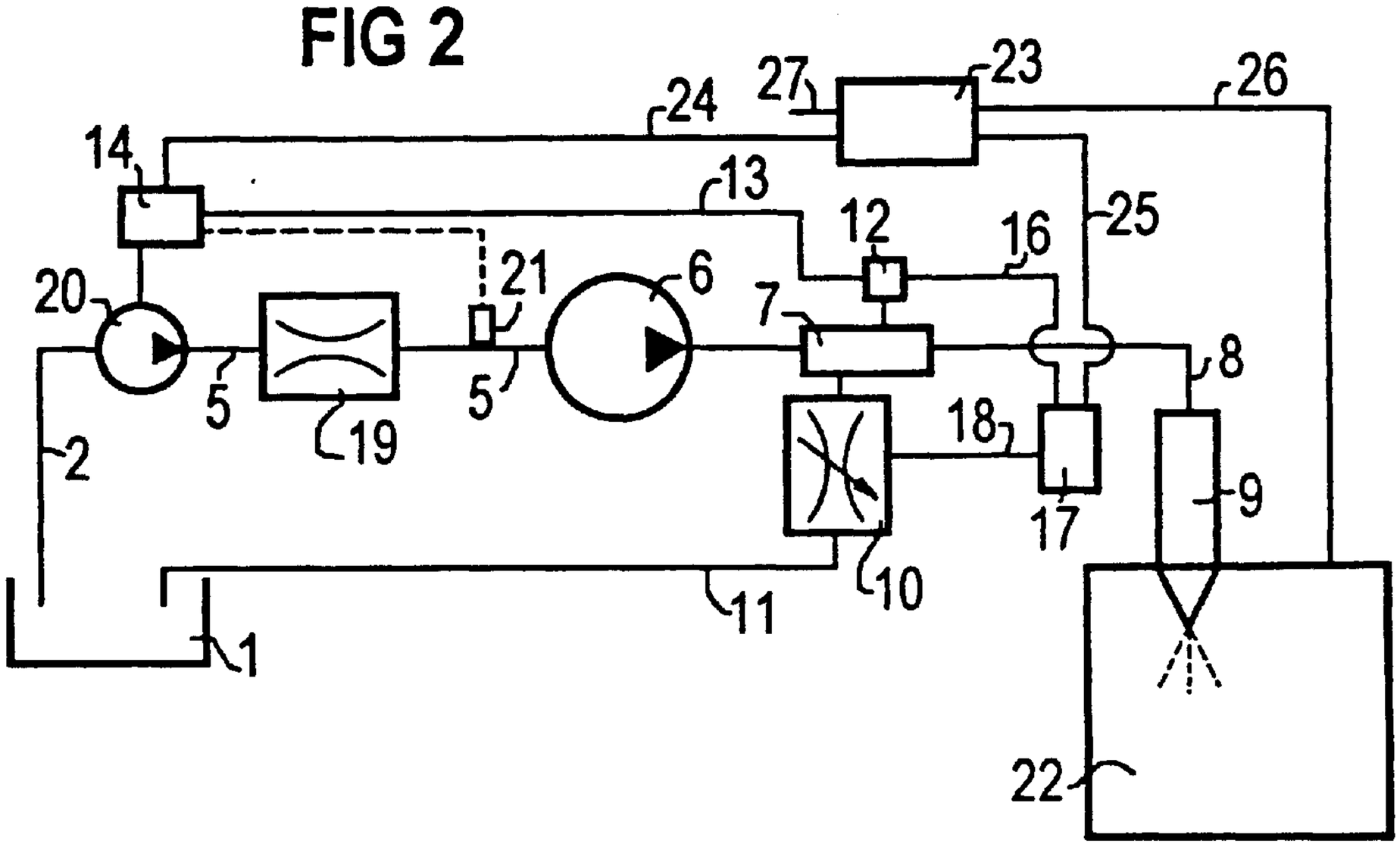
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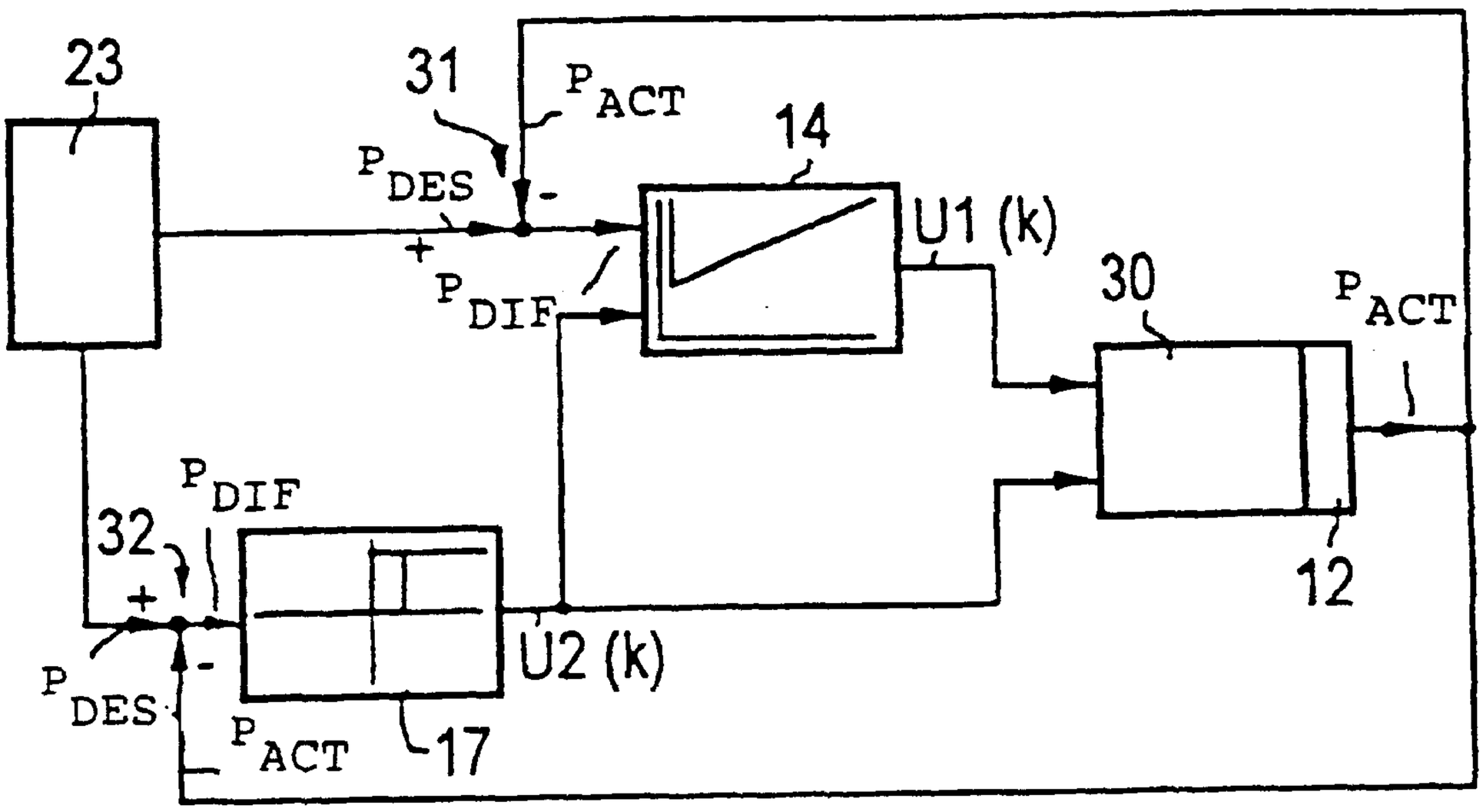
FIG 3



DEVICE AND METHOD FOR REGULATING THE FUEL PRESSURE IN A HIGH-PRESSURE ACCUMULATOR

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of International application Ser. No. PCT/DE97/00902, filed May 2, 1997, which designated the United States.

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The invention relates to a device for regulating the fuel pressure in a high-pressure accumulator, including a controller for a volumetric flow in an inflow to a high-pressure pump connected to the high-pressure accumulator, and a pressure sensor assigned to the high-pressure accumulator and signaling the fuel pressure in the high-pressure accumulator to the controller. The invention also relates to a method for regulating the fuel pressure in a high-pressure accumulator for fuel, which includes supplying fuel to the high-pressure accumulator through a high-pressure pump, discharging fuel from the high-pressure accumulator through an injection system, and regulating the volumetric flow of fuel upstream of the high-pressure pump in a low-pressure region as a function of the pressure in the high-pressure accumulator.

High-pressure accumulators for fuel are used in common-rail injection systems. In that case, fuel is pumped into a high-pressure accumulator by a high-pressure pump, and the fuel is supplied to individual injection nozzles from the high-pressure accumulator. That makes it possible to have a high injection pressure which reduces the emission of particles, particularly in diesel injection.

Published European Patent Application 0 299 337 A2, corresponding to U.S. Pat. No. 4,884,545, has already disclosed a device for regulating the fuel pressure in a high-pressure accumulator as well as a method for regulating the fuel pressure in a high-pressure accumulator. In that case, fuel is supplied by a pre-feed pump, through a controllable throttle, to a high-pressure pump which pumps the fuel into the high-pressure accumulator at high pressure. The high-pressure accumulator conducts the fuel further to the injection nozzles and has a safety pressure valve which connects the high-pressure accumulator to the fuel tank when the maximum pressure is exceeded. The controllable throttle is activated by a control unit as a function of operating parameters of the internal combustion engine, so that a regulation of volumetric flow is carried out on the low-pressure side.

The disadvantage of the device and the method described in the prior art is that a reduction of pressure in the high-pressure accumulator can take place only relatively slowly, since the controllable throttle cannot be used for pressure reduction.

SUMMARY OF THE INVENTION

It is accordingly an object of the invention to provide a device and a method for regulating the fuel pressure in a high-pressure accumulator, which overcome the hereinafore-mentioned disadvantages of the heretofore-known devices and methods of this general type, which allow a rapid pressure reduction and which moreover have high efficiency.

With the foregoing and other objects in view there is provided, in accordance with the invention, a device for regulating the fuel pressure in a high-pressure accumulator, comprising a high-pressure pump connected to a high-pressure accumulator having a fuel pressure to be regulated, the high-pressure pump having an inflow; a first controller having a continuous control behavior for controlling a volumetric flow in the inflow to the high-pressure pump; a second controller having a step-by-step control behavior for controlling the fuel pressure in the high-pressure accumulator; and a first pressure sensor associated with the high-pressure accumulator, the first pressure sensor reporting the fuel pressure in the high-pressure accumulator to the first controller, and the first pressure sensor reporting the fuel pressure in the high-pressure accumulator to the second controller.

In accordance with another feature of the invention, the first controller has an input, and the second controller has an output fed to the input of the first controller.

In accordance with a further feature of the invention, there is provided a controllable feed pump for regulating the volumetric flow in the inflow to the high-pressure pump.

In accordance with an added feature of the invention, there is provided a constant throttle disposed downstream of the controllable feed pump.

In accordance with an additional feature of the invention, in addition to or instead of the first pressure sensor, there is provided a second pressure sensor disposed upstream of the high-pressure pump; and a measuring line connecting the pressure sensor to the first controller.

With the objects of the invention in view, there is also provided a method for regulating the pressure in a high-pressure accumulator for fuel, which comprises supplying fuel through a high-pressure pump to a high-pressure accumulator; discharging fuel from the high-pressure accumulator through an injection system; regulating a volumetric flow of fuel in a low-pressure region upstream of the high-pressure pump as a function of the pressure in the high-pressure accumulator; regulating the pressure in the high-pressure accumulator in a high-pressure region as a function of the pressure in the high-pressure accumulator; regulating the volumetric flow of fuel in the low-pressure region when the pressure in the high-pressure accumulator is lower than a trigger pressure; and regulating the pressure in the high-pressure accumulator when the pressure in the high-pressure accumulator is higher than the trigger pressure.

In accordance with another mode of the invention, there is provided a method which comprises regulating the volumetric flow when the pressure in the high-pressure accumulator exceeds the trigger pressure.

In accordance with a further mode of the invention, there is provided a method which comprises regulating the volumetric flow as a function of the pressure regulation.

In accordance with a concomitant mode of the invention, there is provided a method which comprises ascertaining the trigger pressure from a sum of a desired value and a threshold value.

The device and the method according to the invention afford the advantage of carrying out quasi-stationary changes in the fuel pressure by a regulation of volumetric flow on the low-pressure side and carrying out dynamic changes in the fuel pressure by pressure regulation on the high-pressure side. In this way, the advantage of the high efficiency of a regulation of volumetric flow on the low-pressure side, combined with the advantage of the high dynamics of pressure regulation on the high-pressure side

and improved dynamics, with an efficiency higher than that of pressure regulation on the high-pressure side, are thereby achieved.

Other features which are considered as characteristic for the invention are set forth in the appended claims.

Although the invention is illustrated and described herein as embodied in a device as well as a method for regulating the fuel pressure in a high-pressure accumulator, it is nevertheless not intended to be limited to the details shown, since various modifications and structural changes may be made therein without departing from the spirit of the invention and within the scope and range of equivalents of the claims.

The construction and method of operation of the invention, however, together with additional objects and advantages thereof will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block circuit diagram of a high-pressure accumulator with a preceding volumetric flow regulating valve;

FIG. **2** is a block circuit diagram of a high-pressure accumulator with a preceding controllable feed pump; and

FIG. **3** is a block circuit diagram with a diagrammatic illustration of a regulating method.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the figures of the drawings in detail and first, particularly, to FIG. **1** thereof, there is seen a tank **1** which is connected through a fuel inlet line **2** to a feed pump **4**. The feed pump **4**, which is not controllable, is connected through a feed line **5** and a regulating valve **3** to a high-pressure pump **6**. An outlet of the high-pressure pump **6** is connected to a high-pressure accumulator (common-rail) **7**. The high-pressure accumulator **7** has an injection line **8** which is led to an injector **9** of an internal combustion engine **22**. The high-pressure accumulator **7** is connected through a pressure-regulating valve **10** and a fuel return line **11** to the tank **1**.

Furthermore, a pressure sensor **12** is disposed at the high-pressure accumulator **7**. The pressure sensor **12** is connected through a first measuring line **13** to a first controller **14** which is connected through a first control line **15** to the regulating valve **3**. Moreover, the pressure sensor **12** is connected through a second measuring line **16** to a second controller **17** which is connected through a second control line **18** to the pressure-regulating valve **10**.

The first controller **14** and the second controller **17** are respectively connected through a first data line **24** and a second data line **25** to a computing unit **23**, which is moreover connected through a third measuring line **26** to the internal combustion engine **22**. Furthermore, the computing unit **23** has input lines **27**, through which various input values, such as an accelerator pedal position of the motor vehicle, for example, are received. Instead of the pressure sensor **12**, according to a development of the invention, a second pressure sensor **21** may be used for feeding the first controller **14**. The second pressure sensor **21** is disposed in the feed line **5** upstream of the low-pressure side of the high-pressure pump **6** and is connected to the first controller **14**. The regulating valve **3** can thus also be regulated according to the pressure in the feed line **5**.

FIG. **2** shows a configuration corresponding to that of FIG. **1**, but in which a controllable feed pump **20** is provided instead of the non-controllable feed pump **4**. The controllable feed pump **20** is controlled through the first control line **15** by the first controller **14**. A further difference is that the regulating valve **3** is dispensed with and a constant throttle **19** is inserted between the controllable feed pump **20** and the high-pressure pump **6**, instead of the regulating valve **3**. The configuration of FIG. **2** corresponds in other details to the configuration of FIG. **1**, with identical parts being provided with the same reference symbols.

According to a development of the invention shown in FIG. **2**, a second pressure sensor **21** for feeding the first controller **14** is used instead of the pressure sensor **12**. The second pressure sensor is disposed in the feed line **5** upstream of the low-pressure side of the high-pressure pump **6** and is connected to the first controller **14**.

The controllable feed pump **20** can thus also be regulated according to the pressure in the feed line **5**.

FIG. **3** shows a diagrammatic illustration of the regulating method according to the invention. A desired pressure P_{DES} is predetermined for the high-pressure accumulator according to the operating state of the internal combustion engine **22**. In the following example, it is assumed, on the basis of the operating state of the internal combustion engine **22**, which includes, for example, the engine speed, the load and the exhaust-gas values, and using the input data supplied by the input lines **27**, such as the position of the accelerator pedal, for example, that the computing unit **23** ascertains the desired pressure P_{DES} for the high-pressure accumulator **7** and predetermines it for a first comparator **31** and a second comparator **32**.

The pressure sensor **12** likewise transmits the current actual pressure of the high-pressure accumulator **7** to the first comparator **31** and to the second comparator **32** as an actual pressure P_{ACT}. The first comparator **31** and the second comparator **32** subtract the actual pressure from the desired pressure and ascertain therefrom a differential pressure P_{DIF}: $P_{DES}-P_{ACT}=P_{DIF}$.

The differential pressure P_{DIF} is transmitted from the first comparator **31** to the first controller **14**, which activates the regulating valve **3** in the embodiment of FIG. **1** or the controllable feed pump **20** in the embodiment of FIG. **2**. The differential pressure P_{DIF} is also transmitted from the second comparator **32** to the second controller **17**, which activates the pressure-regulating valve **10**. The first controller **14** is preferably constructed as a PID controller which calculates a current first controller action u1(k) from the differential pressure P_{DIF}, which is designated as a current control deviation e(k) for the following formula. The calculation is carried out according to the following rule:

$$u1(k) =$$

$$u1(k-1) = K\left[\left(1+\frac{T_D}{T_0}\right)e(k) - \left(1+2\frac{T_D}{T_0}-\frac{T_0}{T_1}\right)e(k-1) + \frac{T_D}{T_0}e(k-2)\right]$$

in which:

u1(k) denotes the current controller action,
u1(k-1) denotes the last controller action,
e(k) denotes the current control deviation,
e(k-1) denotes the next to the last control deviation,
K denotes the amplification factor,
T_0 denotes the sampling time,
T_D denotes the differentiating time, and

T_I denotes the integrating time.

In this case, preferably the amplification factor K is 0.2%/M pascal, the sampling time T_0 is 20 msec, the differentiating time T_D is 10 msec and the integrating time T_I is 70 msec. The second controller **17** is preferably constructed as a two-position controller which calculates a current second controller action u**2**(k) according to the following rule:

$$u2(k) = \frac{T_e}{T_z} Ky$$

in which:

y denotes the stationary final value of the desired quantity with the controller at the upper switching point,

K denotes the amplification factor,

T_z denotes the period duration, and

T_e denotes the duty cycle.

In a preferred embodiment of the invention, the stationary final value is 60 M pascal, the amplification factor K is 0.045%/M pascal, the period duration T_z is 2 msec and the duty cycle is 1 msec.

In the exemplary embodiment described herein, the two-position controller **17** switches from its zero value to the current controller action u**2**(k) when P_{DIF} is above a predetermined value which is preferably 100 bar.

In a preferred embodiment, the current controller action u**2**(k) of the two-position controller **17** is transmitted to the first controller **14** which corrects the current controller action of the first controller **14** or stops the regulation, as a function of the current controller action u**2**(k) of the second controller **17**.

The current controller actions of the first controller **14** and of the second controller **17** are supplied to a controlled system **30**. The pressure sensor **12** and/or the second pressure sensor **21** ascertain the pressure in the high-pressure accumulator or upstream of the high-pressure accumulator and transmit the pressure to the first comparator **31** and to the second comparator **32** as the actual pressure P_{ACT}. As is evident from FIG. **1**, the first controller **14** transmits the current first controller action to the regulating valve **3** and the second controller **17** transmits the current second controller action to the pressure valve **10**. According to a further embodiment of the invention, the first controller **14** regulates the controllable feed pump **20** through the use of the current first controller action, as is illustrated in FIG. **2**.

The first and the second controllers **14**, **17** are selectively constructed as analog or digital controllers.

We claim:

1. A device for regulating the fuel pressure in a high-pressure accumulator, comprising:

a high-pressure pump connected to a high-pressure accumulator having a fuel pressure to be regulated, said high-pressure pump having an inflow;

a first controller having a continuous control behavior for controlling a volumetric flow in said inflow to said high-pressure pump;

a second controller having a step-by-step control behavior for controlling the fuel pressure in the high-pressure accumulator; and

a pressure sensor associated with the high-pressure accumulator, said pressure sensor reporting the fuel pressure in the high-pressure accumulator to said first controller, and said pressure sensor reporting the fuel pressure in the high-pressure accumulator to said second controller.

2. The device according to claim **1**, wherein said first controller has an input, and said second controller has an output fed to the input of said first controller.

3. The device according to claim **1**, including a controllable feed pump for regulating the volumetric flow in said inflow to said high-pressure pump.

4. The device according to claim **3**, including a constant throttle disposed downstream of said controllable feed pump.

5. The device according to claim **1**, including another pressure sensor disposed upstream of said high-pressure pump; and a measuring line connecting said pressure sensor to said first controller.

6. A device for regulating the fuel pressure in a high-pressure accumulator, comprising:

a high-pressure pump connected to a high-pressure accumulator having a fuel pressure to be regulated, said high-pressure pump having an inflow;

a first controller having a continuous control behavior for controlling a volumetric flow in said inflow to said high-pressure pump;

a second controller having a step-by-step control behavior for controlling the fuel pressure in the high-pressure accumulator;

a pressure sensor disposed upstream of said high-pressure pump; and

a measuring line connecting said pressure sensor to said first controller.

7. A method for regulating the pressure in a high-pressure accumulator for fuel, which comprises:

supplying fuel through a high-pressure pump to a high-pressure accumulator;

discharging fuel from the high-pressure accumulator through an injection system;

regulating a volumetric flow of fuel in a low-pressure region upstream of the high-pressure pump as a function of the pressure in the high-pressure accumulator;

regulating the pressure in the high-pressure accumulator in a high-pressure region as a function of the pressure in the high-pressure accumulator;

regulating the volumetric flow of fuel in the low-pressure region when the pressure in the high-pressure accumulator is lower than a trigger pressure; and

regulating the pressure in the high-pressure accumulator when the pressure in the high-pressure accumulator is higher than the trigger pressure.

8. The method according to claim **7**, which comprises regulating the volumetric flow when the pressure in the high-pressure accumulator exceeds the trigger pressure.

9. The method according to claim **7**, which comprises regulating the volumetric flow as a function of the pressure regulation.

10. The method according to claim **7**, which comprises ascertaining the trigger pressure from a sum of a desired value and a threshold value.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO : 5,941,214

DATED : August 24, 1999

INVENTOR(S) : Christian Hoffmann et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the title page:

Item [30] should read as follows:

May 10, 1996 [DE] Germany 196 18 932.2

Signed and Sealed this
First Day of February, 2000

Attest:

Q. TODD DICKINSON

Attesting Officer

Acting Commissioner of Patents and Trademarks